ULTRAFAST RECOVERY DIODE

RELATED APPLICATION

This Application is related to co-pending, commonly owned U.S. patent application Ser. No. 10/869,718, entitled "Schottky Barrier Rectifier and Method of Manufacturing the Same," filed Jun. 15, 2004, which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

An important factor in the efficiency of a switching power supply is the performance of the diodes used in such circuits. More particularly, the reverse recovery of such diodes can reduce turn-on loss of the transistor switch in such power supplies. For example, a reverse recovery current transient appears as an additional component of current during the turn-on of the switch, with the result that the turn-on loss of the switch is significantly higher that it would otherwise be without such reverse recovery component. Consequently, reducing metal oxide semiconductor field effect transistor (MOSFET) body diode reverse recovery charge (Qrr) and/or reducing reverse recovery time (trr) is important for improving the efficiency of switching power supplies.

Unfortunately, however, if the reverse recovery is too abrupt, then the current and voltage will experience undesirable oscillations. Such oscillations can result in, for example, low efficiency power supply operation, a deleteriously noisy output, e.g., power supply ripple and/or electromagnetic interference, and/or extremely high and possibly damaging voltage spikes.

SUMMARY OF THE INVENTION

Thus, a fast recovery diode with reduced reverse recovery charge that maintains a soft recovery characteristic is highly desired. A further desire exists to meet the previously identified desire in an ultrafast recovery diode that can be formed in either trench or planar versions. Yet another desire exists to meet the previously identified desires in a manner that is compatible and complimentary with convention semiconductor manufacturing processes and equipment.

Accordingly, an ultrafast recovery diode is disclosed. In a first embodiment, a rectifier device comprises a substrate of a first polarity, a lightly doped layer of the first polarity coupled to the substrate and a metallization layer disposed with the lightly doped layer. The ultrafast recovery diode includes a plurality of wells, separated from one another, formed in the lightly doped layer, comprising doping of a second polarity. The plurality of wells connects to the metallization layer. The ultrafast recovery diode further includes a plurality of regions, located between wells of said plurality of wells, more highly doped of the first polarity than the lightly doped layer.

In accordance with another embodiment of the present invention, a semiconductor device comprises a rectifier, wherein the rectifier comprises a plurality of P-type wells coupled to a contactable metal layer. The plurality of P-type wells injects holes into a channel region between the plurality of P-type wells in a forward-bias condition of the rectifier. The plurality of P-type wells pinch off the channel region in a reverse-bias condition of the rectifier. The semiconductor device further includes a plurality of N-type wells located between the plurality of P-type wells. The plurality of N-type wells suppresses minority carrier injection from the plurality of P-type wells.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention are illustrated by way of example and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. **1** illustrates a side sectional view of an ultrafast recovery diode, in accordance with embodiments of the present invention.

FIG. **2** illustrates a side sectional view of an ultrafast recovery diode, in accordance with alternate embodiments of the present invention.

FIG. **3** illustrates exemplary current versus time recovery characteristics, in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with these embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it is understood that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention.

FIG. **1** illustrates a side sectional view of an ultrafast recovery diode **100**, in accordance with embodiments of the present invention. Diode **100** is formed in an N-epitaxial layer **180**. Diode **100** comprises a plurality of trenches **110** with oxide sidewalls **120**. A conductive **130** plug, e.g., comprising Tungsten or Polysilicon, fills trenches **110**, coupling anode metallization **140**, e.g., an anode contact, with p wells **150**. P well regions **150** underlie trenches **110**. P well regions **150** are designed to act as weak anodes. Anode **140** typically comprises Aluminum, and may further comprise about one percent Silicon in some embodiments.

The trenches **110** of diode **100** have exemplary depth dimensions of about 0.3 to 0.7 microns. The trenches **110** of diode **100** have exemplary width dimensions of about 0.3 to 0.6 microns. The trenches **110** have an exemplary pitch of about 0.6 to 1.3 microns. It is appreciated that embodiments in accordance with the present invention are well suited to other dimensions.

In accordance with embodiments of the present invention, regions between p wells **150** comprise n-type doping, referred to as "n channel enhancement" **160**. N channel enhancement **160** comprises exemplary doping of about 1.0×10^{15} to 2.0×10^{16} atoms per cubic centimeter. It is to be appreciated that such a doping level is generally above a doping level N-epitaxial layer **180**. Schottky barrier **170** is formed between the anode metal **140** and the N-epitaxial layer **180**. Schottky barrier **170** may be formed, for example, by inherent characteristics of Aluminum disposed adjacent to an N-epitaxial layer, e.g., anode metal **140** comprising Aluminum disposed adjacent to N-epitaxial layer **180**. Embodiments in accordance with the present invention are well suited to other formations of Schottky barrier **170**.